THE HYPERSPECTRAL IMAGER ABOARD THE SSTI's LEWIS SPACECRAFT: A COMPARISON WITH AVIRIS

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1. INTRODUCTION

This paper compares the performance and operational parameters of the Hyperspectral Imager (HSI), scheduled for launch aboard the Lewis spacecraft in July 1996, with those of the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS). The HSI is a pushbroom, imaging spectrometer with 30 meter spatial resolution, generating 384 spectral channels over the range 400 to 2500 nm at 5.0 to 6.4 nm resolution for each of its 256 crosstrack pixels. The Lewis spacecraft and the HSI are being built by TRW, Incorporated as part of the Small Spacecraft Technology Initiative (SSTI) initiated by NASA's Office of Space Access and Technology to advance the state of technology and reduce program costs associated with the development and operation of small satellites. The SSTI is also producing the Clark spacecraft being built by CTA, Incorporated, which is scheduled for launch late in the summer of 1996. Clark will carry the high spatial resolution WorldView imager, having 3m panchromatic and 15m multispectral capability, as its primary payload.

Because the SSTI was intended to demonstrate new design and space system qualification methods as well as to promote commercial applications for remotely sensed data, both Lewis and Clark will carry a number of additional payloads and experimental technology demonstrations. Among these payloads are two other imaging spectrometers: the Linear Etalon Imaging Spectrometer Array (LEISA) and the Ultraviolet Cosmic Background (UCB) instrument aboard Lewis. The LEISA is an earth-observing sensor providing 256 spectral bands in the 1000 to 2500 nm region, with roughly 300 meter spatial resolution. The UCB is designed to map the diffuse, ultraviolet cosmic background in the 11.8 to 22.5 eV range. Additional Clark payloads include the Atmospheric Tomography (ATOMS) instrument for determining 3-D atmospheric molecular profiles, the Measurement of Air Pollution from Satellites (μMAPS) sensor for mapping and monitoring atmospheric carbon monoxide profiles, and the X-Ray Spectrometer (XRS) for observing solar flares and cosmic gamma ray bursts over the 1 to 100 keV region.

To augment the list of sensor performance metrics, this paper presents the signal to noise ratios of both the HSI and the AVIRIS for typical observing conditions, outlines plans for standard processing of HSI data, and discusses both data availability and satellite tasking.

2. HSI PERFORMANCE AND OPERATIONAL PARAMETERS

Table 1 compares the performance and operational parameters of the AVIRIS with those of the HSI, which is composed of two focal plane assemblies: the Visible- to Near-Infrared (VNIR) and Short-Wave Infrared (SWIR) spectrometers.

Table 1. Comparison of HSI and AVIRIS System Parameters

Parameter	Lewis/HSI	AVIRIS
Operational Altitude	Circular orbit of 523 ± 10 km altitude, Sun Synchronous (97.5° inclination) 10:50 AM ± 0:20 ascending node.	Nominal 20 km operational altitude.
Positional Accuracy	≈ ± 100 m in X, Y, and Z	≈ ± 100 m in X, Y, and Z
Imaging Attitude	• ± 22° in Roll • ± 0.25° in Pitch • ± 3.8° in Yaw	Nadir pointing only.
Attitude Uncertainties	• ± 8" in Roll (≈2/3 pixel) • ± 25" in Pitch (≈2 pixels) • ± 30" in Yaw (≈1/60 pixel)	• ± 21" in Roll (≈1/10 pixel) • ± 21" in Pitch (≈1/10 pixel) • ± 21" in Yaw (≈1/100 pixel)
Data Collection Rate	One imaging event per working day. Approximately 250 image cubes in the first year of operation.	≈80 cubes per flight day or ≈3,000 cubes per year. This includes 33% downtime for scheduled maintenance.
Radiometric Calibration Plan	• Pre-launch laboratory calibrations • 8 pre-image dark frames • 8 post-image dark frames • 8 post-image white frames at low lamp current • 8 post-image white frames at high lamp current • 1 set of solar frames per week • Periodic, on-orbit calibration verification experiments	• A pre-image sequence of darks, whites, and line frames • A post-image sequence of darks, whites, Lyots, and Line frames • Yearly laboratory calibration • Three operational calibration experiments annually
Radiometric Calibration Accuracy	• ± 5% absolute • ± 2% relative	• ± 4% absolute • ± 2% relative
Data Quantization	12-bit digitization, padded to a two-byte integer	12-bit digitization, padded to a two-byte integer
Spectral Calibration Plan	• Pre-launch calibration • On-orbit verification • Periodic on-orbit monitoring	• Annually in laboratory • ± 1 nm band centers • ± 1 nm band widths full width half max (FWHM)
Spatial Resolution	30m by 30m pixels	20m by 20m nominal pixels
Spatial Size of Data Sets	• 256 cross track pixels • ~1000 along track lines but more in proportion to the fraction of bands *not* acquired	• 614 cross track pixels • 512 along track lines
Spectral Resolution	• VNIR → 5.0 nm FWHM • SWIR → 6.4 nm FWHM	≈10 nm for all spectrometers (A, B, C , and D)
Spectral Sampling	• VNIR → 5.0 nm • SWIR → 6.4 nm	≈10 nm for all spectrometers (A, B, C, and D)
Number of Bands	• VNIR → 128 (400 - 1000 nm) • SWIR → 256 (900 - 2500 nm)	• A → 32 (370 - 680 nm) • B → 64 (670 - 1270 nm) • C → 64 (1250 - 1880 nm) • D → 64 (1880 - 2500 nm)

3. SIGNAL-TO-NOISE RATIOS

Figure 1 compares the signal-to-noise ratios expected from both the HSI and the AVIRIS for a target at 45°N latitude, having a gray albedo of 0.3, an observing geometry with 60° solar zenith angle, using a standard, MODTRAN spring season atmosphere. The signal-to-noise ratios for both VNIR and SWIR are plotted in the 900 nm to 1000 nm region where they overlap.

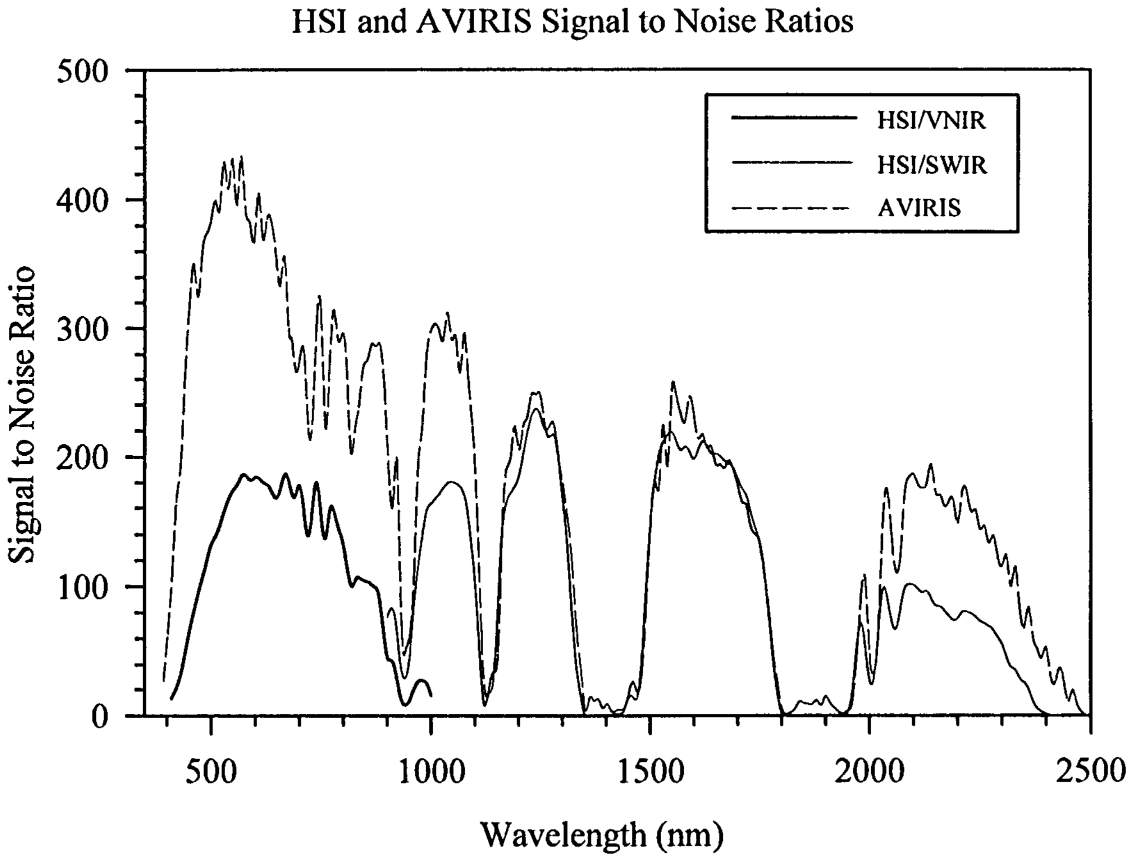

Figure 1. The signal-to-noise ratios expected from both HSI and the AVIRIS for a target at 45° N latitude, having a gray albedo of 0.3, an observing geometry with 60° solar zenith angle, using a standard, MODTRAN spring season atmosphere. The VNIR and SWIR spectral channels have been binned in twos to produce resolutions of 10 nm and 12.8 nm for VNIR and SWIR respectively, comparable with that of the AVIRIS. Both VNIR and SWIR spectra are plotted in the 900 nm to 1000 nm region where they overlap.

4. DATA PROCESSING

The Commercial Remote Sensing Program (CRSP) based at Stennis Space Center (SSC), Mississippi, is developing the Data Processing System (DPS) to derive higher-level data products from level 0 HSI data acquired at the spacecraft. The purpose of the DPS is to optimize the commercial and scientific viability of the Lewis and Clark missions by offering the entire user community standard data products, appropriate to their requirements, for further processing and analysis. The data processing outline of the DPS is 1) radiometric calibration, where signal digital numbers are converted to units of radiance at the spacecraft; 2) atmospheric removal, where molecular absorptions as well as molecular and aerosol scattering effects are removed, thus converting pixel units to apparent ground reflectance; 3) georeferencing of both VNIR and SWIR spectrometers, where the latitude and longitude of each image pixel center are determined relative to a featureless Earth model (NOTE: there is no data resampling here); 4) the SWIR data are spatially resampled, producing a footprint on step 3's model Earth equivalent to that of VNIR; and 5) the region of spectral overlap between VNIR and SWIR is removed, yielding one complete, apparent reflectance spectrum for each image pixel. The DPS will also perform a number of automated quality assurance (QA) steps and allow for manual QA at every level. All DPS processing will be performed using C++ and IDL codes running in the Windows NT operating system on INTEL-based machines. Processing to level 2 data products and beyond will be accomplished manually by SSC staff for Lewis team members on an as-requested basis.

5. DATA AVAILABILITY

Appropriate data products from the DPS described in section 4 will be made available to all Lewis team partners via the World-Wide-Web-based Mission Data Management System (MDMS). This system will allow team partners to examine all data sets and to download chosen image cubes and associated data structures (*i.e.*, data headers, metadata, parameter blocks, and calibration data structures) directly. Copies of appropriate data within the MDMS will be stored at the EROS Data Center (EDC), where they will be made available to the public following EDC and NASA established pricing guidelines. Generally, there will be no period of exclusivity for SSTI data products, and all SSTI data will be made available immediately following DPS processing. However, data collected in response to national emergencies and for Code S sponsored investigations will retain a one-year period of exclusivity for government use and the Code S experiment team, respectively.

Although subject to change, it appears that the MDMS will contain the following data generated by the DPS for each imaging event: 1) an unprocessed, level 1A cube (prior to step 1 above); 2) a 1G1 cube, which has been converted to georeferenced, apparent reflectances on the ground (processed through step 3 above, NOTE: having undergone no irreversible processing); and 3) a 1R2 cube, containing one complete spectrum per image pixel (processed through step 5 above, NOTE: resulting from both spatial and spectral irreversible processing). Higher-level (data levels 2 and beyond) information products will *not* be made available from within the MDMS environment or at the EDC.

6. LEWIS/HSI TASKING

Current NASA/SSTI data policy is to establish an Experiment Tasking Oversight Group (ETOG), which will review all satellite tasking requests in each of the four basic experiment areas: commercial, science, education, and technology demonstrations. Proposals from current Lewis team partners will be given precedence over those from non-members, who will be required to enter into a Space Act Agreement with NASA, including appropriate experimental results reporting, in order to submit tasking proposals for ETOG consideration. In cooperation with NASA, CRSP, and TRW personnel, the ETOG will generate the tasking priorities among the four general experiment types and establish a coordinated tasking and observation plan. This plan will conform with all existing NASA data policies, including contingencies for national emergencies and natural disasters.

7. ACKNOWLEDGMENTS

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